

Sustainability in City-Building Games

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ABSTRACT

Sustainability is a topic of concern in the design of modern cities. In the interest of evaluating how popular media may reflect this value, we modified an indicator-based framework designed for evaluating the sustainability of real-world cities to fit virtual cities. We then applied this modified framework to seven video games in the city-building genre and examined how each category of indicators (water, land use, energy, clean air, social wellbeing, population density, and trade) was represented in each game. We found that social wellbeing played the most significant role in the long-term success of a city: cities with poor wellbeing struggled to maintain or increase population. Additionally, we found that games with pre-industrial settings generally rewarded sustainable practices while the industrial and post-industrial games did the opposite. Post-industrial games also significantly prioritized city growth over sustainability. Thus, the setting was a significant predictor for modelling sustainability.

Keywords

Sustainability, city-building videogame, triple bottom line, city development, videogame, Anno 1880, Cities: Skylines, Dawn of Man, Frostpunk, Pocket City, Sim City: BuildIt

INTRODUCTION

Sustainability, the idea that humanity should be able to maintain a social, environmental, and economic balance (Egger 2006), is vital to the long-term survival of life on our planet (World Commission on Environment and Development 1987). Given the gravity of the current situation, it can be interesting to explore how sustainability and sustainable practices are represented and modeled in popular media, including games. What does our media say about sustainability and how it is communicated? (Starosielski and Walker 2016) We wonder what, if anything, games might communicate representationally and/or procedurally about sustainability. A deeper understanding of game designs incorporate ideas about sustainability can allow us to better understand and critique them. In a sense, we are attempting to answer Abraham and Jayemanne's (2017) question: "Where are all the climate change games?", but for sustainability instead of climate change.

Rather than examine a breadth of games, we focus on the genre of city-building games where players manage resources (human, natural, etc.) to build and develop a simulated human settlement (e.g. village, city). Players operate as both city planner and mayor. Player's tasks generally include placing buildings, providing utilities and services, managing finances, and creating infrastructure (e.g., roads, sewers), though this varies depending on the setting and complexity of the game (Bereitschaft 2016). We chose this genre because it is potentially the most aligned with sustainability. For instance, there could be parallels with the literature on sustainability in cities and urban environments. Also, city-building games have been called "complex games" due to

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their simulation elements, dynamic systems, and emergent properties and behavior (Glean 2005) and might therefore employ procedural rhetoric (Bogost 2007) to communicate ideas about sustainability.

Procedural rhetoric is the “the practice of using processes persuasively” (Bogost 2007) to communicate ideas about how systems work. Bogost (2007) argued that games have the potential to illustrate and communicate complex ideas through their gameplay and that players can access these ideas through play. As an example he discusses how *The McDonalds Videogame* (Molleindustria 2006) makes an argument about the systemic problems in the global fast food industry such that commercial success inevitably requires (amongst other things) engaging in corruption (Bogost 2007). Other scholars have studied military propaganda in games (Demers 2014), sought to better understand genre (Harper 2011), or looked at games’ arguments about immigration policy (Cleger 2015). We examine the genre of city-building games to better understand what, if anything, they might express with regards to sustainability and how they go about doing so. Are there commonalities or significant differences across titles? Are some issues ignored? Which issues are salient? And more.

To answer these questions, we analyzed recent city-building games to see how they model and represent sustainability and sustainable practices. For example, do they allow for renewable energy and resources? What are the impacts of pollution? We speculated that most games required engaging in unsustainable practices: e.g abusing the environment by polluting and depleting natural resources to succeed. Similarly, we believed that even when sustainable options are available, they occur late in the game and are unattractive to players in terms of their benefits. Thus, we think these games reward play behaviors contrary to sustainable practices and ignore the costs of unsustainable development.

Sustainability

Commonly prevailing definitions of sustainability rely on two ideas: longevity (Lorr 2012; Mori and Christodoulou 2012; Morris 2004; Tanguay et al. 2010) and the holistic concept of the triple bottom line (Dunn and Hart-Steffes 2012; Egger 2006; Elkington 2006; Mori and Yamashita 2015; Yan et al. 2018). Longevity requires that the needs of the current generation are met without compromising the needs of future generations (World Commission on Environment and Development 1987). The triple bottom line explains sustainability as a focus on three dimensions: Social, Environmental, and Economic (Slaper 2011). The inclusion of social and economic dimensions may run counter to commonplace notions that sustainability is limited to environmental factors. However, these dimensions are vital for understanding the variety of factors that interact with the environment (Dunn and Hart-Steffes 2012). This three-dimension concept is also often referred to as the 3 P’s (people, planet, and profits).

In the triple bottom line, the social dimension refers to the importance of considering the wellbeing of the individuals within the community. This can include measures such as health, safety, and unemployment. If these measures suffer, the results may impact the other dimensions – too many sick laborers can lower production, or high unemployment can limit a governments’ tax income. The environmental dimension involves preserving natural resources, such as water, land, and flora/fauna. Destroying these resources can cause other issues such as insufficient food supply for a community or an inability to harvest goods that could have been sold. Finally, the economic dimension requires a consistent flow of capital. This means that, in the case of a city, its inhabitants and local businesses must keep making money in order to pay their expenses or facilitate growth. Financial instability can impact the funds needed to provide services to residents or to gather resources for production.

The triple bottom line is popular because it considers how relationships between dimensions can impact sustainability. Most governments consider it when evaluating sustainability in real cities (Mori and Christodoulou 2012), making it highly applicable for evaluating city-building games.

However, balancing the triple bottom line for a brief period is insufficient – sustainability requires ongoing stability to meet the needs of both current generation and future generations (World Commission on Environment and Development 1987). In using the triple bottom line and the idea of longevity, sustainability is understood as the need to ensure the social, environmental, and economic balance long term (Dunn and Hart-Steffes 2012).

Sustainability and Games

The literature on sustainability and games is often framed as “environmental communication, ‘sustainable media’, ‘eco-media’, or ‘green popular culture’” (A. Chang and Parham 2017). There are three broad areas of inquiry: (1) studying the game industry’s sustainability, i.e. the production, manufacture, distribution, and sale of its products and the demands of the technology required to use them (e.g. Mazurek 1999; Milburn 2014), (2) the design and use of games as tools useful to communicate and educate about sustainability (e.g. Chapman 1973; Tragazikis and Meimaris 2009; Bell-Gawne et al. 2013; Meadows, Booth Sweeney, and Martin Mehers 2016; Fjællingsdal and Klöckner 2020) including meta-analyses of sustainability in serious games (Stanitsas, Kirytopoulos, and Vareilles 2019), and (3) the critical analysis of videogames’ content and meaning (e.g. Abraham 2018; Milburn 2018; A. Y. Chang 2019). Scholars have also studied the sustainability of videogame play as an activity. For example, by looking at the energy consumption of dedicated gaming computers (e.g. Chuah, Yuen, and Cheung 2014; Mills and Mills 2016).

City-Building Games

Moss argues that *The Sumer Game* “was the first computer game to concern itself with matters of city building and management” (Moss 2015). Since then, numerous titles have built upon that concept, adding features and gameplay that loosely define the genre called city-building games. As described earlier, these are generally open-ended games where players manage resources in the process of creating and developing a simulated human settlement.

SimCity (Maxis 1989) is widely considered an exemplar of the genre (Moss 2015; Bereitschaft 2016) with multiple sequels released over the years. The genre has also expanded thematically, for example including fantasy (e.g. *D&D Stronghold*, *Zeus: Master of Olympus*) and science-fiction (e.g. *Aven Colony*, *Surviving Mars*) environments.

METHODS

Game Selection

Our primary goal when selecting city-building games was achieving an overview of their design space via exemplar titles. We limited ourselves to games released between 2014 and 2019 to ensure our results were current to the genre. To find games, we checked the Steam PC store for the term “city-building game” and performed online searches for articles on city-building game releases for multiple platforms including game consoles and mobile devices. We combed through these results for games that involved building and managing the infrastructure of a city as their primary mechanic, eliminating those focused on managing an individual household (e.g. *The Sims 4*) or those that prioritized another mechanic over city-building (e.g. empire building in *Civilization VI*). This process resulted in 18 games. For each game we then examined

its marketing materials and reviews. We excluded games with consistently poor reviews as we felt they were not exemplar titles of the genre. We also ignored add-ons and DLC, preferring to look at the base game. This left us 16 titles.

Since a broad overview would help us achieve coverage of the primary types of city-building games, we identified loose categories and then “placed” each game within. Our first category was “Realism” or how closely the game seemed to represent the world as we know it (e.g. humans living on Earth). Second, we considered the scale or size of the city-building activities identifying two common types: town and city. Finally, we categorized games based on their (approximate) time period: prehistoric, pre-industrial, industrial, present, and future. We also categorized games by platform and payment model. These categories are not precise. Our use is not for precision but rather to ensure coverage of the salient thematic representations of the genre.

We then decided to exclude science-fiction, fantasy, and futuristic games as issues involving sustainability faced on other planets/fantasy worlds may be inaccurate or irrelevant when compared with sustainability in real-world cities. We also avoided using multiple titles in the same series to cover more perspectives.

We then created a table with the remaining 11 games with rows and columns for our differentiating categories. From this table, we selected one game that met each combination of our criteria. When multiple games met the same combination of criteria, we prioritized those with higher popularity and sales, as being more “representative” of the genre as a whole. The selected games are shown in Table 1.

Title	Time Period				Size/Scale	
	<i>Pre-Industrial (Pre-Historic)</i>	<i>Pre-Industrial (Modern)</i>	<i>Industrial (1800s)</i>	<i>Post-Industrial</i>	<i>Town</i>	<i>City</i>
Anno 1800 (Blue Byte 2019)			X			X
Banished (Shining Rock Software 2014)		X			X	
Cities: Skylines (Colossal Order 2015)				X		X
Dawn of Man (Madruga Works 2019)	X				X	
Frostpunk (11 bit studios 2018)			X			X
Pocket City (Codebrew Games 2018)				X		X
SimCity: BuildIt (TrackTwenty 2014)				X		X

Table 1: Selected Games for Analysis

Framework for Analysis

With our games selected, we needed to determine and understand what “sustainable” might mean within games. To our knowledge, there aren’t any sustainability frameworks for analyzing the sustainability of virtual/game cities. However, there is research on sustainable practices and a variety of frameworks for measuring

sustainability in real-world cities. Thus, we needed to select an existing framework for measuring sustainability and adapt it for analyzing city-building games.

We articulated criteria to help select a framework. We wanted to measure various indicators of environmental, economic, and social sustainability to develop a full understanding of our game city’s sustainability. We also wanted to account for the longevity of sustainability, considering how future generations would be affected by current in-game behaviors. Finally, we needed a framework that could be practically applied to a virtual city. The measurements that many real-world cities collect are more complex than those used in most games, so our assessment could not rely on those precise calculations. Similarly, many games don’t track certain information or make it available to the player – so we needed a framework we could use without that level of detail or access to source code.

The most used frameworks are indicator-based. These track indicators of how a city is performing in social, environmental, and economic categories(Hiremath et al. 2013). For example, indicators for a category of water use may include gallons of fresh water consumed, quality of water supply, and percent of wastewater treated. There are many such frameworks, each varying in which indicators are used to measure a given category. Indicators have been found to be highly effective for measuring the complexities of sustainability (Hiremath et al. 2013). They’re most effective, however, when applied evenly across every city using a manageable number of measurements (Tanguay et al. 2010).

We selected the assessment index system described in Yan and colleagues’ urban sustainable development case study (Yan et al. 2018). This framework considers the impact of a city through input and output indicators, calculating the sustainability of a city through its relative efficiency. The three inputs are the natural resources provided by the environment. The eight outputs describe the impacts humans have, including the environment and the economic and social dimensions of city sustainability. For instance, the square meters of land used for construction could be an indicator of the input of natural land, while an output indicator could be measured by acres of undeveloped land. We found this particular indicator-based framework to be a comprehensive measurement of sustainability, yet potentially applicable to virtual cities and broad enough to be applied evenly across each of our games.

Category	Description
Water	The consumption of fresh water and disposal of waste water
Land Use	How much land is developed on and how much land is left natural (undeveloped)
Energy	How much fuel is consumed to provide energy for each person
Clean Air	How many days of the year have air above a certain quality metric
Social Wellbeing	How the needs of individual citizens are met, measuring quality of life, education, and life expectancy
Population Density	How much habitation space each person has
Trade	How much the city contributes to other cities

Table 2: Indicators for City-Building Sustainability, adapted from Yan et. al (2018).

However, at this stage we lacked clarity on how to use and interpret each element of the framework when examining city-building games. So, we used a game that was not selected for the study as a pilot. We played 20 hours of *Tropico 4* (Haemimont Games 2011) and took notes on every aspect of the game that matched the 11 indicators from Yan and colleagues' framework (2018). Here we realized the need for modifications.

First, some of the (original) 11 indicators are usually measured/presented together within games. This prompted us to refine the framework by combining some indicators into a seven category framework (Table 2).

Second, we could not directly apply the measurements from Yan et al.'s framework. For example, while every residence in a real city consumes a measurable amount of water, games generally don't calculate such a minute detail. Further, even when measurements were tracked, they might not be consistent across games: e.g. different titles might use "a tile", an acre, or some other measure as a unit of land. So, instead of utilizing the precise measurements in Yan et. al. (2018) (e. g. ton of water per person), we developed a set of descriptive indicators for collecting information regarding indicators in the original framework. These descriptive indicators are framed as questions targeting what we needed to look for. We describe these below:

- **Water:** Are there mentions/representations of pumping systems or pipes, thirst, residential or commercial water access, sewage, or water pollution?
- **Land Use:** Are there measurements of available green land, how much of the land was developed, presence of resources (e.g. trees, animals, rock, ore), and ground pollution?
- **Energy:** Are there resources used as fuel or to create energy? Are there structures used to generate fuel or energy (e.g. power plants)? Is there mention of how or where energy is used? Are there problems arising from lack of energy and structures where energy is needed?
- **Clean Air:** Are air pollution, noise pollution, and impacts of air cleanliness measured, represented, and/or reported?
- **Social Wellbeing:** Are there measurements of happiness, health, living standards, employment, education, and any other quality of life measurements? What factors impacted these measurements?
- **Population Density:** Are any of the following tracked or communicated: population, birth and death rates, and reasons citizens may migrate to or from the city?
- **Trade:** Are there situations where outsiders exchange goods or money with the city? How is currency is gained, tracked, and spent, and what does import and export of resources look like, if present?

With our framework adjusted, we began applying it. We played all seven games, taking detailed notes for each with columns for the seven indicators. In these notes, we described every instance of each indicator and how it was represented. This included measurements, mechanics, or text mentioning the indicators. We played each game long enough to develop a strong familiarity with all mechanics and reach a point where all content was revealed/used. This was determined differently for each game. We played *Dawn of Man*, *Cities: Skylines*, and *SimCity:BuildIt* for a minimum of 30 hours to unlock all available buildings and/or technologies. For *Frostpunk*, we completed the main scenario – A New Home – twice, playing both the Path of Faith and the Path of Order. *Pocket City* allows players to level up indefinitely, so we reviewed player discussions and the developer's comments on the game's Discord channel and Reddit. From this we determined that the main content of the game is unlocked at level 60, so we played *Pocket City* through that achievement. *Banished* and *Anno 1800* allow

players to unlock all the buildings within a few hours, so we examined each game's respective wiki to ensure no new mechanics or buildings appeared later on. Upon confirming this, we played a minimum of 30 hours in each game to ensure we had thoroughly explored the mechanics.

After playing each game we began analyzing our data. We wanted to determine whether there might be patterns, commonalities, or unexpected connections across games. We synthesized the notes from each game into one chart with columns for each game, rows for indicators, and details in the cells on how each indicator was represented in each game. We color coded cells that described similar uses of an indicator to identify patterns across multiple games which we then synthesized allowing us to better identify connections.

FINDINGS

We now report on our findings for each of the seven indicators from our game-city sustainability framework: water, land use, energy, clean air, social wellbeing, population density, and trade. For each, we describe how they are represented in different games highlighting notable features.

Water

Water generally plays up to three roles in city-building games: a resource to be utilized or consumed, a source of food, and an enabler for transportation.

All citizens need access to fresh water through water collection mechanics in *Cities: Skylines*, *Dawn of Man*, *Pocket City*, and *SimCity: BuildIt*. Villagers in *Dawn of Man* collect buckets of water from rivers and lakes by hand, while buildings in the three post-industrial games receive access if they are close enough to water pipes.

While water intake is present in all four of these games, wastewater surprisingly only exists in *Cities: Skylines* and *SimCity: BuildIt*. Both games allow the player to pump sewage into a body of water with or without prior treatment. Furthermore, water treatment plants are expensive, late-game buildings providing minimal benefits. Treatment plants in *SimCity: BuildIt* don't cause pollution (unlike untreated sewage pumps), and in *Cities: Skylines* they are only necessary if the sewage begins to contaminate the fresh water supply. This concept of contamination makes *Cities: Skylines* unique, in that it doesn't consider every water source to be fresh and potable.

Considering how many games incorporate water use, we expected representations of wastewater and the consequential water pollution. Even in *Cities: Skylines*, there is no mention of ecological damage caused by dumping raw sewage.

Water is also used indirectly as a source of food. *Anno 1800*, *Banished*, and *Dawn of Man* include a fishing mechanic. Fish are spread evenly throughout each body of water and replenish over time. Overfishing in one area prevents the population from recovering in *Dawn of Man* and *Banished*. Notably, *Banished* does not inform the player of this concept – instead, they learn through trial and error.

Finally, water is a method of transportation in *Banished*, *Anno 1800*, and *Cities: Skylines*. All three incorporate trade by boat. Tourists arrive on ships in *Anno 1800* and *Cities: Skylines*, providing income for the city. *Anno 1800* also allows players to control ships for diplomatic quests and warfare.

Water is commonly featured in city-building games and generally treated as a resource. However, the management and treatment of wastewater or the need to treat/process

water for human consumption is rarely included. Water is generally considered an unlimited resource in all of the games studied.

Land Use

Unsurprisingly, land is a key resource in city-building games through both direct and indirect uses.

Land is used for development in all seven games. It is paved over for buildings, streets, and even city parks. Land is always a finite resource. *Anno 1800* and *Frostpunk* employ natural boundaries (e.g. cliffs) to restrict where players can build. All three post-industrial games initially provide access to one parcel of land, with surrounding parcels available for purchase later.

Land is also used directly to store city's physical waste. Garbage must be collected and disposed of in *SimCity: BuildIt* and *Cities: Skylines*. Both offer waste management in the form of garbage dumps and incinerators, with *SimCity: BuildIt* adding recycling. Garbage dumps are available at lower levels and are the cheapest to build, but they require more land. Recycling plants and incinerators are more expensive and must be unlocked at higher levels. For example, a small garbage dump in *SimCity: BuildIt* has a capacity of 15 units of garbage and costs 6000 simoleons. The first available recycling facility's capacity is 70 units of garbage and costs 60,000 simoleons. The cost of 5 small dumps is half as expensive and with greater capacity than one recycling center. Similarly, *Cities: Skylines* limits players to a 4,000 dollar landfill until they can afford the 30,000 dollar incineration plant made available at the sixth level.

Since only *Cities: Skylines* and *SimCity: BuildIt* include mechanics for managing garbage, they are the only games in which waste causes pollution. Similarly, land pollution caused by industry and powerplants only exists in *Cities: Skylines*, *SimCity: BuildIt*, and *Anno 1800*. Pollution results in neighboring citizens becoming unhappy or sick and lower land value. There is no mention of damage to local plants, animals, or soil. Considering how significant the problem of industrial pollution and waste is in real world cities, it's surprising to see so little attention on pollution in these games.

Death is also treated as a form of "waste". In *Dawn of Man*, *Banished*, *Frostpunk*, and *Cities: Skylines* lower population happiness is caused by corpses left in homes instead of being managed appropriately. These games offer burial via cemeteries or burial mounds which take up space but lessen the negative impact on happiness. *Cities: Skylines* also offers a crematorium which diminishes the need for burial space but is not available until the eighth level. *Frostpunk* also allows for preserving the dead in a pit of snow, which does not take up land.

Most of these games also use land indirectly as a source of resources. While *SimCity: BuildIt* does not recognize that its building materials come from the environment, the other two post-industrial games acknowledge that natural resources exist and that some land is more fertile than other land. Players have no responsibility to care for the environment, however, and depleting resources is not a concern. Money plays a more important role, allowing players to purchase resources from other cities instead of gathering them directly. While all of these games use land, the post-industrial games are more distanced from its use and preservation. The industrial-era games, meanwhile, place a heavier focus on gathering natural resources as a vital means of collecting supplies and trade income. While most resources (e.g. clay, iron) are available in infinite supply, the post-industrial games incorporate some finite resources such as abandoned ruins and fallen trees. Finally, the pre-industrial games focus on the collection of resources for survival. Many renewable resources such as plants, animals, and trees take time to regenerate, and overuse of such resources can cause deforestation,

overhunting, and extinction. Practices such as mining and quarrying produce natural resources, but create irreversible scars on the land. Players are taught to mitigate their actions by allowing time for regrowth, farming their own food sources, and in *Banished*, foresters even help the environment recover by planting new trees.

The last way that land is used is for recreation and entertainment. All three post-industrial games as well as *Anno 1800* incorporate some indicator to assess land value. This measures the proximity, number, and quality of parks, recreation lots, and landscaped areas. Land value has a significant effect on the happiness of local citizens.

We found that land value interestingly prioritizes man-made parks over natural open space. While *Pocket City*, *SimCity: BuildIt*, and *Cities: Skylines* calculate a higher land value for beachfront property, landlocked natural land isn't valuable. Citizens demand access to man-made parks, creating an odd situation where players are encouraged to pave over natural land to build "unnatural" parks.

Clean Air

Clean air is rarely acknowledged in these games and is only referenced when pointing out pollution. *Cities: Skylines* is the only game to include noise pollution, which comes from industrial areas, infrastructure (e.g. power plants), and highways. It has a negative impact on the land value nearby, causing unhappiness and complaints. While *Pocket City* frequently mentions that environmentalist choices can improve air pollution, we are unaware of mechanics or systems included to support this.

Like our findings with pollution of land and water, air pollution is surprisingly absent from these games. It is unclear in *Anno 1800*, *Cities: Skylines*, and *SimCity: BuildIt* how much of the pollution described affects the ground versus the air, so it's possible that these games intended to address clean air but illustrate it subtly. However, there are so few mentions of pollution in any form that these games do not accurately represent the air quality problems that real world cities face.

Finally, while traffic is treated as a social problem in all three modern games, it is oddly not one of air quality. While traffic is a source of noise pollution in *Cities: Skylines*, it does not create air pollution.

Social Wellbeing

Social wellbeing is represented in a variety of ways, but primarily through happiness, population health, public safety, and education.

Happiness is calculated in every game and usually represented via a numerical score (and accompanying graphic). Its role is central for player success since unhappy citizens desert cities and migrants are drawn to happier ones. Worker productivity is also affected, as unhappy workers are less productive. The tourists of *Cities: Skylines* and *Anno 1800* prefer to patronize happy cities. In *SimCity: BuildIt*, citizen income taxes even increase with happiness, directly impacting the city's income. Several factors contribute to happiness, as it is used in these games to represent social wellbeing as a whole. However, the way it is calculated is bespoke to each game. In *Pocket City*, for example, happiness is broken down as a factor of availability of recreation, quality of environment, crime safety, health, fire safety, traffic congestion, traffic accessibility, and tax satisfaction. Meanwhile happiness in *Frostpunk* is measured simply as a balance of hope and discontent meters, and later through obedience, faith, and/or fear meters.

Health is present in some form in all seven games. The pre-industrial and industrial games have a lower-level focus on individual health, employing mechanics for illness

and, except in the case of *Anno 1800*, mechanics for injuries. Poor diets, cold weather, and pollution can cause illness, while injuries result from warfare or dangerous jobs such as hunting. Left untreated, poor health lowers happiness and worker productivity. Extreme cases result in death, or in the case of *Frostpunk*, occasional amputations. Except for *Dawn of Man*, however, these games each have some form of medical facility for ill or injured citizens. In contrast, the three post-industrial games take a higher-level approach to health. In these games, health focuses on the number and proximity of healthcare facilities, as well as proximity of pollution, rather than focusing on individual injuries and illnesses. An insufficient number of nearby healthcare facilities lowers happiness in these games.

Public safety concerns in these games are represented via crime/police, fires, and natural disasters. *Banished*, *Anno 1800*, and the three post-industrial games combat fires with wells or fire stations. Police stations handle crimes and riots in each of the industrial and post-industrial games. Natural disasters occur in *Pocket City* and *SimCity: BuildIt*, and though these don't result in any injuries or deaths, the player must purchase replacements for destroyed buildings.

The final significant factor in wellbeing is education. All games, except *Dawn of Man*, include some kind of school mechanic. Citizens in *Anno 1800* and *Cities: Skylines* become unhappy without sufficient access to schools. Education is optional in the other games, but it can provide happiness or other perks. Highly educated adults in *Cities: Skylines* can work in office buildings, which provide greater tax income for the city. Students in *Banished* become more efficient adult workers. *Frostpunk* offers the "child shelter", which allows children to apprentice in medicine or engineering – providing extra labor to those fields.

One notable finding is that citizens with poor social well-being have differing levels of recourse, varying between the time periods in which each game is set. Citizens in the pre-industrial games can't do anything about their conditions. They have no way to complain or leave if their needs aren't met. These pre-industrial games take a personal approach to describing poor wellbeing, allowing the player to view statistics for each villager and lessening the focus on average wellbeing of the village. Players can address low wellbeing by instructing individual villagers to eat, go home, etcetera instead of continuing to work.

In the three post-industrial games, unhappy citizens complain regularly. If ignored for too long, they abandon the city. Displayed wellbeing statistics are much more general, encouraging the player to focus on the happiness of neighborhoods and regions more than that of individual citizens.

In the industrial games, players have slightly more individual statistics similar to the pre-industrial games but can only make improvements at a larger scale like in the post-industrial games. However, unhappy citizens riot if their complaints aren't addressed. Rioters quit working, cause damage, and convince others to join them – and, if the movement isn't subdued, *Frostpunk's* rioters abandon the city. This is interesting, as the industrial games are generally the middle ground between pre-industrial and post-industrial rather than the extreme.

Depending on the game's time period, social well-being is operationalized at different scales. Pre-industrial games focus on individual members of society while the post-industrial games present players with well-being at the societal level –individual citizens could be unhappy, but the player is unable to directly influence their well-being as in the pre-industrial games.

Population Density

As significant as population is to these games (see Social Wellbeing earlier), population density plays a surprisingly small role. Only the post-industrial games discuss different densities for each size of land that can be developed. *Pocket City* describes residential lots as small, medium, and large, and indicates the amount of water they each need - 50, 100, and 200 respectively. There is no mention, however, of the number of residents in each building. *Cities: Skylines* allows low density and high-density residential zones, but is not specific as to how many families live in each. Residential lots take up varied space, making it virtually impossible to calculate the difference between house and apartment capacity. *SimCity: BuildIt* shows buildings growing in size as the player purchases improvements to them, but there is no reference to how many people live in each one.

The aspect of population density more relevant in these games is more about how many people can fit within the city than about the density of each lot. In all of the games (except *Frostpunk*), population cannot increase through immigration or birth unless sufficient housing is provided. However, new citizens in every game require resources and infrastructure to support their social wellbeing. If social wellbeing drops, population will drop as citizens die and/or, in the case of the post-industrial games and *Frostpunk*, choose to move out. So, population density is a measure of capacity in these games – how many citizens the city can physically house and meet the social needs of. This is, of course, different from what happens in real-life cities: the capacity of a city to handle a population is elastic and flexible – rather than a hard limit.

Population density is vaguely mentioned in the post-industrial games. There are no specific measurements given for it. The most involvement the player has in population density is through zoning in *Cities: Skylines* or upgrading residential lots in *Pocket City* and *SimCity: BuildIt*. However, in considering population density on a larger scale as the density of the entire city, there is a maximum number of citizens that each city's housing and infrastructure can support across all games. If this population density is exceeded, social wellbeing drops and citizens will die or move out.

Trade

Trade is present in every game (except *Frostpunk*), either through barter of goods or through exchange of goods for money. Both pre-industrial games use barter, while the remaining games use currency.

Cities that use barter engage in little trade. They must wait for an infrequent nomadic trader. The exchanges favor the trader, making trade expensive. Additionally, traders carry few goods, making it hard for the player to sustain their city from trade. Cities with currency, however, engage in trade constantly. *Anno 1800* and *SimCity: BuildIt* allow players to negotiate deals, and cities in all four games with currency can seek out trade at any time – often without the player actively controlling the process.

These differences impact cities beyond trade deals. Bartering cities can't easily import what they need. Thus, they are forced to interact with the environment constantly to meet their needs. Additionally, since they can't purchase building supplies, bartering cities take a more hands-on approach to construction – laborers must collect specific resources and spend time building to create any new structure. Meanwhile, cities with currency don't maintain such a close relationship with the environment because they can purchase whatever they need. These cities can produce new structures without gathering resources, time, or laborers – the player simply pays a flat fee and instantly has a new building. *Anno 1800* and *SimCity: BuildIt* do still require construction resources, but allow players to purchase those resources from foreign cities – essentially allowing players to assemble any structure if they have the money.

Trade also correlates positively with sustainability – it can be used to generate wealth and profit from excess resources and goods that would have otherwise gone unused. The post-industrial games engage in significantly more trade than the pre-industrial cities do, making the former more sustainable in terms of trade than the latter.

Energy

Energy is present in some form in every game we played. At its simplest, wood is fuel in the pre-industrial games. *Dawn of Man* villagers use fires to cook, while those in *Banished* freeze in the winter without enough firewood for their homes. In the industrial and post-industrial games, energy is more widely employed. Except for in *Anno 1800* (which introduces electricity much later in the game), every building needs access to electricity to function. Energy is also present as a source of pollution in *Cities: Skylines* and *SimCity: BuildIt*, as pollution surrounds all power plants. This can be avoided by using renewable energy in both games, which is produced by solar farms, wind turbines, and dams. These sources do still produce noise pollution in *Cities: Skylines*, however. Clean alternatives are predictably more expensive, and must be unlocked long after the polluting power plants are available. Since pollution doesn't exist in *Frostpunk*, *Anno 1800*, or *Pocket City*, clean energy is irrelevant in those games.

DISCUSSION

We found that not all seven indicator categories (water, land use, energy, clean air, social wellbeing, population density, and trade) are equally significant and represented across the genre of city-building games. Of these, social wellbeing made the most significant difference in a city's sustainability. Land use was also vital to sustainability across all the games. Water, energy, and trade played lesser roles in the survival of a city, and population density and clean air were inconsequential and barely present in any of the games.

The fact that social wellbeing is perhaps the most significant and sophisticated (in its representations, mechanics, and systems) across most of the games came as a surprise. Beyond the basic measures of happiness and morale, we found 14 different factors contributing to social wellbeing across the seven games - with some titles focusing only on basic food and health needs and others expanding to cover working conditions, traffic, and even access to luxury goods. Social wellbeing was also the most important indicator of player success: low social wellbeing can cripple an otherwise sustainable city. Considering that environmental sustainability is a more widely discussed aspect of sustainability in our society, it's surprising to see it presented as having less of an impact on a city's success than social sustainability.

While land use was less frequently employed through mechanics than social wellbeing, it was still very present across every game. However, we did expect to see vital resources such as water and energy play a similarly significant role. A lack of water or power in the games that utilize them can destroy a city's population within minutes, yet these still play smaller roles mechanically.

We were surprised by the contrast between each game's time-period setting. The pre-industrial games demonstrated a closer relationship with the environment, encouraging players to preserve the natural land and build smaller, less invasive villages. From an economic perspective these villages engage minimally in trade, and socially the villagers have few desires beyond basic human needs such as water and shelter. Meanwhile, the post-industrial games encourage nearly opposite behaviors. Tax income and trade are vital, and citizens must be kept happy in addition to healthy and safe. These cities are encouraged to sprawl with no concern for the natural land, to import what they need instead of manually gathering natural resources, and to largely disregard pollution and waste. While the pre-industrial games skewed towards

environmentalism, their balance of the triple bottom line is overall more sustainable than the balance we noticed in the post-industrial games. We saw this dichotomy as a telling reflection of the real world – cities often focus more on money, convenience, and the desires of citizens than on the natural land we destroy to achieve these things, choosing to distance ourselves from the environmental damage we cause instead of addressing it.

We didn't find notable differences across platforms and payment models. The differences between village and city scale games were more significant, but it was unclear if they were due to the setting: the only village-scale games were pre-industrial. We found no differences between prehistoric or modern settings for pre-industrial games.

Finally, we considered what it would take to create a sustainable city in the post-industrial games. The benefits of environmentally friendly options such as renewable energy production, are insufficient in offsetting the cost of the more expensive facilities. Also, they are unavailable until reaching higher levels. Thus, pollution-free cities cannot be created from the start. Players must pollute and dump waste, possibly preventing further damage with new facilities later. Even then, while some facilities avoid pollution, most only mitigate it. For a city to have sufficient power, waste management, and transportation, it would be nearly impossible to prevent all pollution. So, while the post-industrial games manage economic and social needs well, they don't give the same treatment to environmentalism. As a result, cities will be impacted by pollution, destruction of natural resources, and lack of land to build on – making them, overall, unsustainable.

CONCLUSION

Our goal was to examine a sample of city-building video games to understand if (and how) they modelled and represented sustainability. To do so, we modified an existing framework (Yan et al. 2018) for evaluating the sustainability of a city so we could apply it to game-cities. In applying our modified framework, future studies will be able to measure the sustainability of other virtual cities.

Our findings show that while environmentally responsible options are sometimes offered in city-building games, they aren't rewarded effectively – if at all. With mechanics (and dynamics) that encourage economic and social growth over environmental conservation, and minimal discussion of how actions impact the environment, players are incentivized to build unsustainable cities. Unfortunately, this seems to mimic the way that our society approaches the triple bottom line. Curiously, the exceptions were the two pre-industrial games we studied, which have a subtle environmental message. The balance that the pre-industrial games create between maintaining human needs, working in tandem with the environment, and supplementing the village through trade models a more sustainable city.

To be fair, it was not the case that sustainability (and its principles) were not present in city-building games at all. Rather, that there wasn't necessarily a balance between the important factors articulated by the research literature. Social well-being and the economic aspects, for example, were central elements of both gameplay and representation. City-building games' "weak link" is the environmental aspect which is rarely present or consistent with the realities of the real-world. Also, we note that we have purposefully ignored how some of these games' settings affect both the player experience (e.g. make some sustainability aspects more salient) and the game's systems/mechanics themselves: e.g. *Frostpunk*'s alternative history Victorian-age

setting puts the player in a situation of survival in which unfettered growth is challenging, notwithstanding issues of sustainability.

Whether or not these issues are a concern depends on the degree to which players practices and understanding of sustainability are affected by playing these games outside of an explicit learning or educational context (e.g. using a city building game to explicitly teach about sustainability). However, that is beyond the scope of this work.

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